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Nitrogen dioxide from OMI: Air-mass factors, a-priori model profiles and stratospheric NO2 assimilation results

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Introduction

In Europe, a new, community best-effort algorithm for the retrieval of NO2 columns has been developed by a consortium of institutes including IUP Bremen, BIRA-IASB, Max Planck Institute for Chemistry, and KNMI (European project QA4ECV, *talk by Folkert Boersma, Thursday*). This algorithm will be used to generate long time series of nitrogen dioxide from the sensors GOME, SCIAMACHY, GOME-2 and OMI. Major parts of this algorithm will also be used to generate the NO2 products of TROPOMI (Copernicus Sentinel-5P).

In our contribution we will focus on the modelling and radiative transfer aspects and separation between stratosphere and troposphere, which are needed to convert the DOAS slant columns into tropospheric vertical columns. Compared to DOMINO-2 nearly all parts of the algorithm have been updated/re-written. The topics are:

- A-priori profiles from high-resolution global chemistry modelling with the TM5 model.
- Estimates of the stratospheric NO2 column by assimilating the observations in TM5.
- Air-mass factors, cloud radiance fractions.
- Improved cloud treatment and use of observations over snow/ice covered terrain
- Error modelling.

TM5 chemistry modelling

DOMINO-2 was based on the TM4 chemistry model (for stratospheric column estimates and tropospheric profiles) run at 3x2 degree. In QA4ECV / TROPOMI / DOMINO-3 we have advanced this to:

1. TM5 run at 1x1 resolution
2. Update of the stratospheric NOx chemistry: nudging with Odin HNO3 climatology
3. Speed-up of the code: new interface to MPI parallel TM5, speed up of assimilation (otherwise about 200x slower than domino-2)

=> 2-3 months of OMI NO2 processed in 1 day

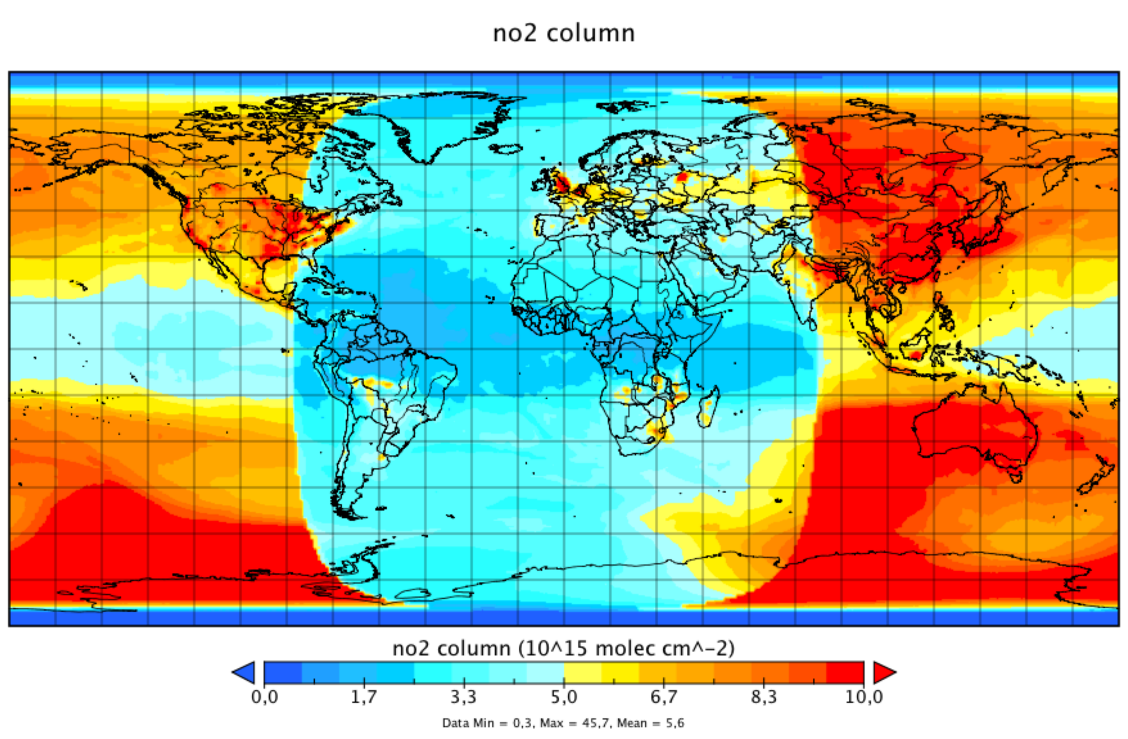

Fig.1. TM5 modelled total NO2 column at 1x1, 21 Sept 2005, 12 utc.

Stratospheric NO2 assimilation

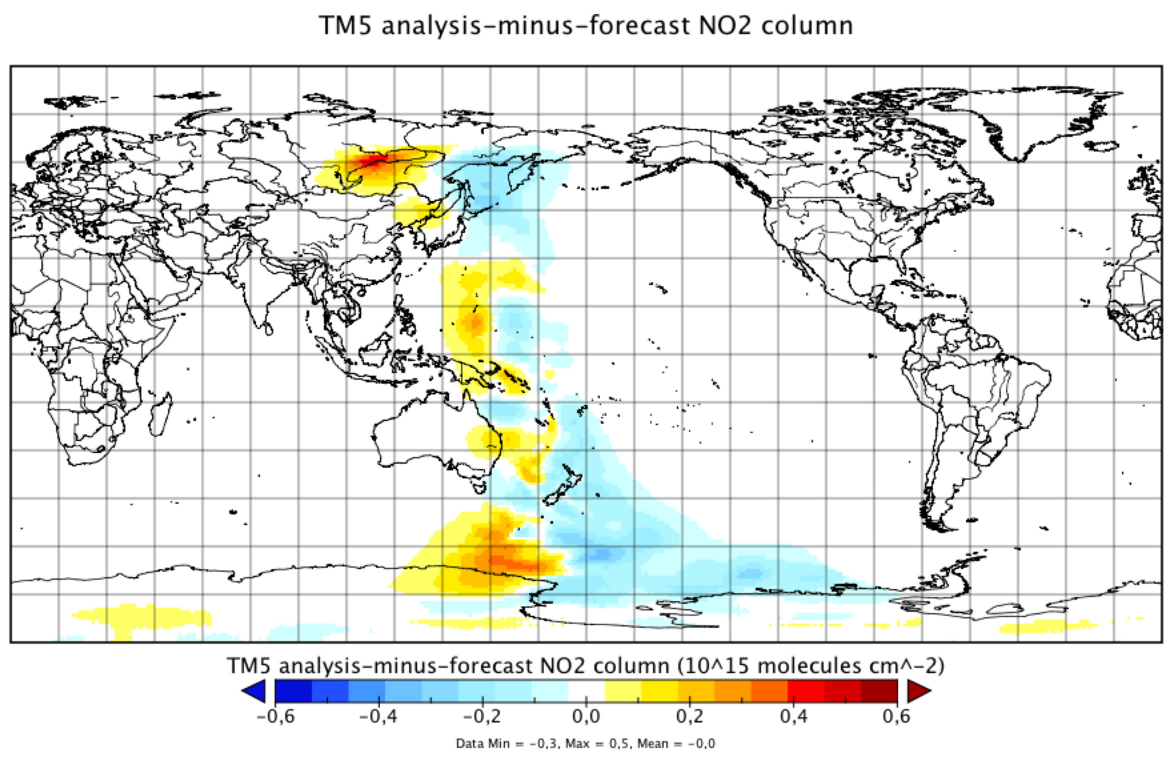

Fig.2. Example of analysis-minus-forecast statistics, 31 January 2005, orbit 2910. The stratospheric assimilation has been optimised compared to DOMINO-2, leading to a stronger forcing to the observations for clean regions. On average, bias(OmF) is close to = 0, but we observe an East-West gradient, which is apparently related to a more pronounced diurnal cycle in TM5 compared to the observations.

Error modelling

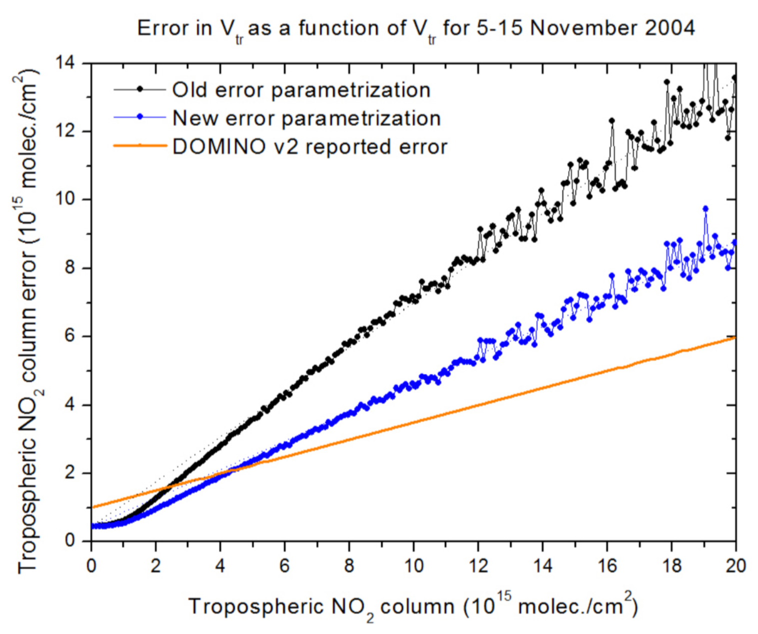

Fig. 3. Change in the modelled uncertainty between DOMINO-2 (black) and the new algorithm (blue) [picture taken from master thesis Bram Maasakkers]. The old DOMINO algorithm is known to be too conservative in it's error estimates. Albedo and cloud uncertainty contributions have been updated. The quality of the slant columns has improved considerably as indicated by a-posteriori SLC uncertainty estimates (Talk Marina Zara)

Clouds

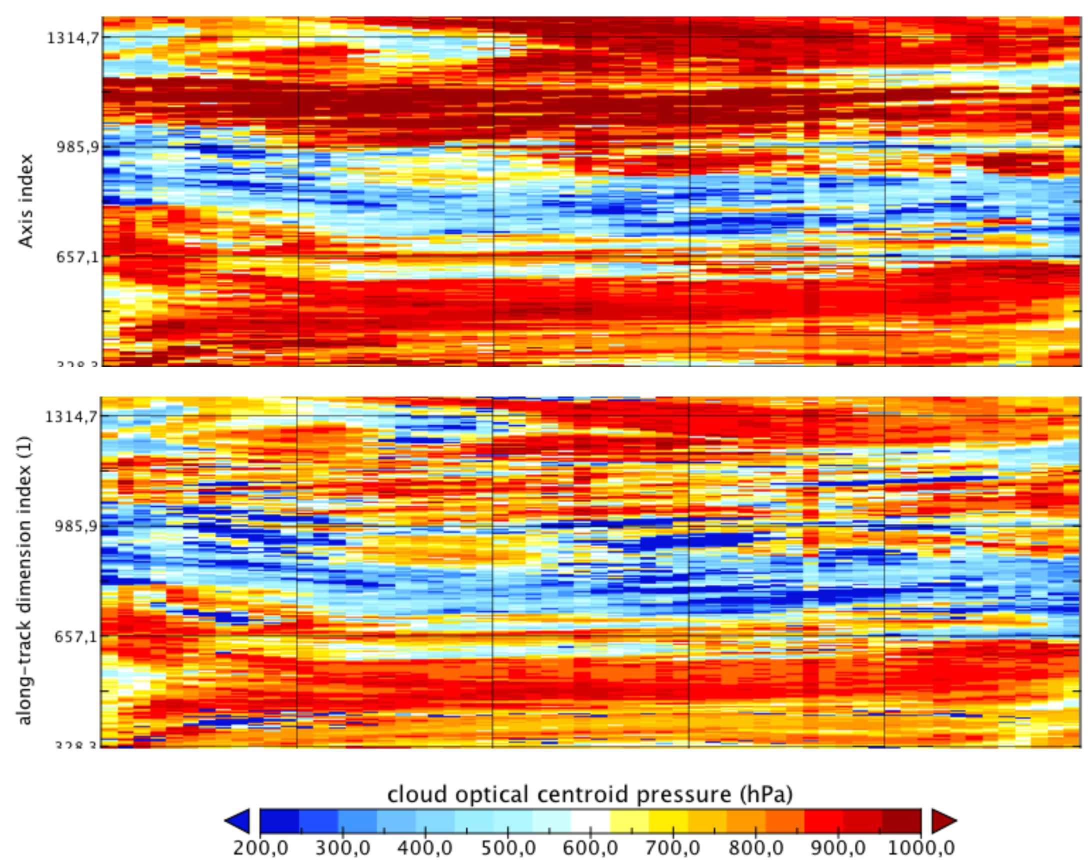

Fig. 4. Cloud pressures in the domino-2 product (top) and new OMI cloud product (bottom) [Veefkind et al., 2016]. Significantly higher cloud tops are derived, which impact the AMFs, especially also for lower cloud fractions. The computation of the cloud radiance fraction has also been improved (modest changes compared to domino-2 of order 1-2%). Snow-ice retrievals, which were rejected earlier, are now included by default (switch to scene pressure). Surface albedo is updated to Kleipool 5yr.

Air mass factors

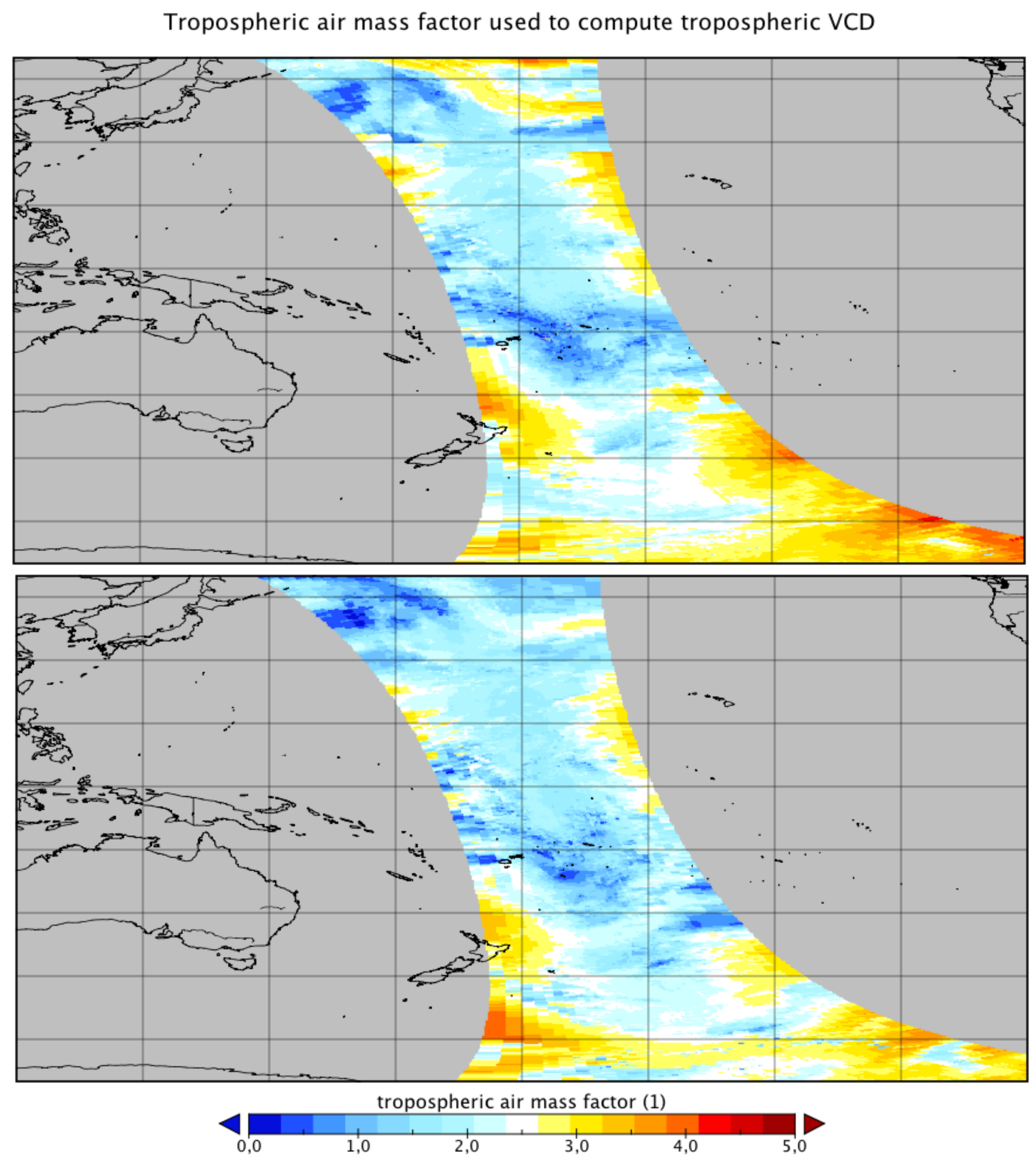

Fig. 5. Air mass factors for DOMINO-2 (top) and QA4ECV (bottom). Noteable features are a large increase in reference points, to minimise interpolation errors, and an empyrical correction for sphericity effects neglected in the RTMs. The box AMF has been extensively compared with other RTM calculations (talk Alba Lorente). Note that the differences observed in the figure are partly related to the new cloud product.

Destriping

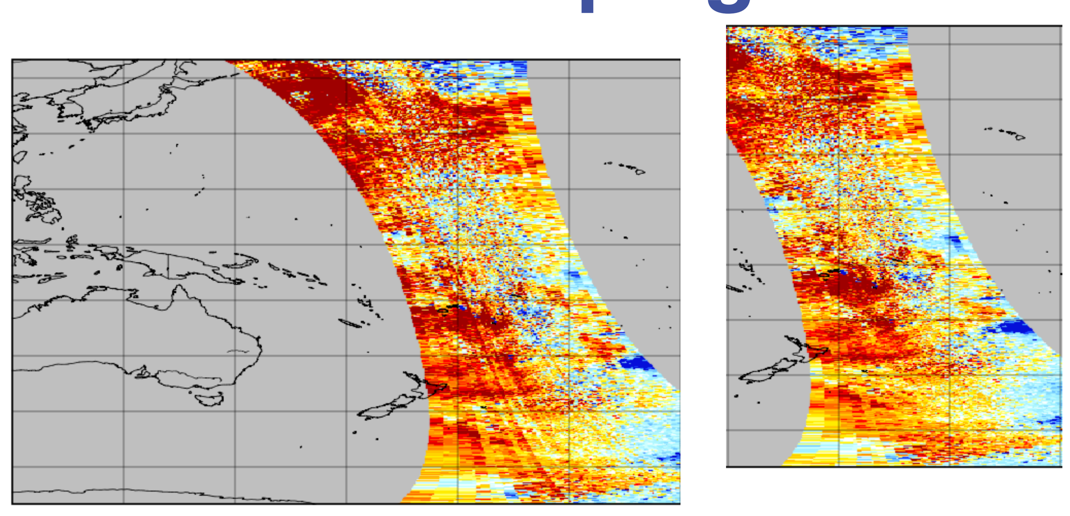

Fig. 6. Example of the tropospheric VCD of one Jan. 2005 orbit over the pacific without (left) and with (right) destriping applied. In domino-2, destriping was applied as a post-processing step. In the new processor the destriping is performed before the assimilation step, determined from orbits over the Pacific, for latitudes near the equator, using the (SLC-SLC_model) difference, and applying corrections to the SLC.

References

Talks by:

1. Folkert Boersma
2. Alba Lorente
3. Marina Zara

Lorente et al, Structural uncertainty in air mass factor calculation process for NO2 and HCHO satellite retrievals, preprint 2016

Veefkind et al., Improvements of the OMI O2-O2 Operational Cloud Algorithm … AMT Discussion 2016.

Bram Maasakkers, Vital improvements to the retrieval of tropospheric NO2 columns from OMI, master thesis, 2013.